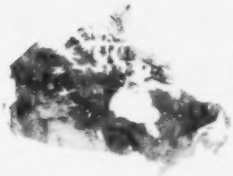

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Time since fire map, age-class distribution and forest dynamics in the Lake Abitibi Model Forest

Sylvie Gauthier, Patrick Lefort, Yves Bergeron and Pierre Drapeau

Laurentian Forestry Centre
Information Report LAU-X-125
2002

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ABSTRACT

There is an emerging agreement that sustainable forest management strategies should be based on a good understanding and knowledge of disturbance regime and forest dynamics. In this context we have undertaken a study on the fire history and forest dynamics in the Lake Abitibi Model Forest (LAMF). First, using aerial photographs, archival documents, and filed sampling, we created a time since fire map for the entire LAMF. This map allowed us to compute the stand age class distribution, the size distribution of stands, the forest composition in each age class and the fire cycle for different time periods. Our results indicate that large parts of the LAMF have not burned for long time periods, suggesting that in the area, fires are large and that fire intervals at the same location are long. In the last 300 years, the fire cycle length has significantly increased from less than 100 years before 1850 to more than 400 years after 1920. Stands that have not burned for more than 100 years represent 78% of the studied area, including 31% that have not burned for more than 200 years and 13% for more than 250 years. The jack pine, poplar and white birch working groups (WG) occupy larger areas in sites that have burned within the last 100 years than in the older sites whereas the WGs of black spruce and balsam fir increase in importance in sites older than 100 years. The same trends are observed at the species level within each WG. The mean stand age (mean time since fire) is 172 years, implying that the global fire cycle is longer than the usual rotation of the studied area. The difference between the natural age class distribution and the one under an even-aged management system is important as on the one hand it implies the loss of old forest, often considered a key landscape element for the maintenance of biodiversity, or on the other hand, a decrease in allowable cuts due to an elongation of rotation if the natural age class distribution is maintained. We suggest that by varying treatments and by developing forest practices that are aimed at conserving certain structural characteristics of older stands, we can reconcile these two different aspects. To this end, some new practices such as HARP that are currently being tested in the LAMF are promising.

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RÉSUMÉ

De plus en plus, on estime que les stratégies d'aménagement forestier durable devraient s'appuyer sur une bonne connaissance des régimes de perturbation et de la dynamique forestière. C'est dans ce contexte que des travaux portant sur l'historique des feux et la dynamique des forêts ont été entrepris dans la Forêt modèle du lac Abitibi (FMLA). Dans un premier temps, à l'aide de photographies aériennes, de documents d'archives et de relevés de terrain, nous avons produit une carte du temps depuis le dernier feu pour l'ensemble du territoire de la forêt modèle. Cette carte nous a permis de calculer la répartition des classes d'âge, la distribution de la taille des peuplements, la composition forestière par classe d'âge, de même que la longueur du cycle de feu pour différentes périodes. Les résultats indiquent que de grandes parties de la forêt n'ont pas brûlé depuis longtemps, ce qui permet de suggérer que dans la FMLA, les feux sont de grande taille et les intervalles entre deux feux au même endroit sont relativement longs. Au cours des 300 dernières années, la durée du cycle des feux a augmenté de façon significative, passant de moins de 100 ans avant 1850 à plus de 400 ans après 1920. Les forêts n'ayant pas brûlé depuis plus de 100 ans représentent 78 % du territoire, 31 % desquelles

n'ont pas brûlé depuis plus de 200 ans et 13 % depuis plus de 250 ans. Les groupes d'aménagement (GA) du pin gris, du bouleau à papier et du peuplier occupent tous des superficies relatives plus grandes dans les peuplements issus de feux datant de 100 ans ou moins que dans les sites plus âgés, tandis que le GA de l'épinette noire et celui du sapin occupent une superficie plus importante dans les peuplements plus vieux que 100 ans. Généralement, les mêmes tendances s'observent au niveau des espèces au sein des différents GA. L'âge moyen des peuplements forestiers est de 172 ans, ce qui signifie que le cycle des feux dépasse la révolution habituelle du territoire. La différence entre la répartition des classes d'âge naturelle et la répartition résultant du système d'aménagement actuel est importante, car elle signifie soit la perte des forêts surannées, qui sont souvent considérées comme essentielles au maintien de la biodiversité, soit une réduction de la possibilité de coupe en raison de révolutions plus longues, si l'on respecte rigoureusement le cycle des perturbations naturelles. Nous suggérons qu'il est possible de concilier ces deux aspects en variant les traitements et en adoptant des pratiques sylvicoles visant à maintenir certaines caractéristiques structurales des peuplements surannés dans les forêts aménagées. D'ailleurs, certaines pratiques comme la CPHRS, déjà à l'essai dans la FMLA, s'avèrent prometteuse.

INTRODUCTION

Increasing interest in forest ecosystem management and, in particular, in forest management strategies that attempt to emulate natural disturbances has been observed over the last decade (Attiwill 1994; Galindo-Leal and Bunnell 1995; MacDonald 1995; Lieffers et al. 1996; Bergeron and Harvey 1997; Angelstam 1998). Currently, there is considerable agreement that a management approach that maintains stand composition and structures similar to those that characterize natural environments could provide a means of maintaining biodiversity and the essential functions of forest ecosystems (Franklin 1993; McKenney et al. 1994; Gauthier et al. 1996). The logic behind this assumption is that organisms are probably best adapted to the environmental forces they have survived and with which they have evolved over the millennia. Hence, knowledge of characteristics such as age-class distribution and the spatial arrangement of forest stands in natural forest landscapes should be considered as a key indicator for the implementation of sustainable forest management. Such knowledge must also rely on forest succession, a key process that structures ecological diversity and determines the availability of timber supply, habitat type for wildlife species, etc. In the boreal forest, fire is the main natural disturbance type that initiates succession and creates a mosaic of forest stands of different ages and compositions, in conjunction with the physical set-up of landscapes.

Within this context, this research project is aimed at defining the fire regime that prevailed in the area covered by the Lake Abitibi Model Forest (LAMF) over the last 300 years. This knowledge is helping to define the historical age-class distribution of stands in the model forest, together with the spatial extent, organization and composition of forest types. This information is one step towards establishing management guidelines for sustainable forestry in the Clay Belt of Ontario and Quebec.

METHODOLOGY

Aerial photographs from the 1920s and the 1950s were analyzed to determine the forest fire limits. The interpreted aerial photographs were superimposed onto topographic maps (1:250 000). These preliminary maps were further refined by the field sampling of approximately 132 forest stands within areas affected by forest fires. Jack pine (*Pinus banksiana*) trees were sampled in more than 65% of the sites; the populations of this species established an even-aged structure after the occurrence of a fire (Gauthier et al. 1993). Other tree species sampled in this study, in descending order of importance, are black spruce (*Picea mariana*), white birch (*Betula papyrifera*), and trembling aspen (*Populus tremuloides*). Tree age was determined by counting annual rings using a binocular scope and, for dead trees, by cross-dating the unknown chronological sequences with a master dendrochronological chronology (Dansereau and Bergeron 1993). Finally, the forest fire history of this century was further refined by examining the local newspapers and the provincial forest fire archives. Once the information was synthesized onto the topographic maps, it was digitized and further interpreted using Arc/Info and Arc/View (Fig. 1). Uncertain fire limits were plotted using the mid-distance between two sites with different fire years. The surficial geology map of the Ministry of Northern Development and Mines (Mines and Minerals Division) of the entire model forest was digitized. Moreover, the database of the Iroquois Falls Forest (FRI of 1987) was also available in digitized format, and it was implemented in the Arc/View system. Superposition of these layers enabled us to assess vegetation dynamics as a function of time since fire. Finally, exploratory analysis related the relative abundance of jack pine and balsam fir to the time since fire and the surficial deposits.

The age-class distribution, stand size distribution and forest composition by age-class were computed using the time since fire map. To determine the fire cycle, a reverse cumulative area distribution was computed, and changes in fire cycle length were assessed visually (Johnson and Van Wagner 1985). The SAS LIFEREG procedure (SAS Institute 1996) was then used to compute fire cycles for different time periods.

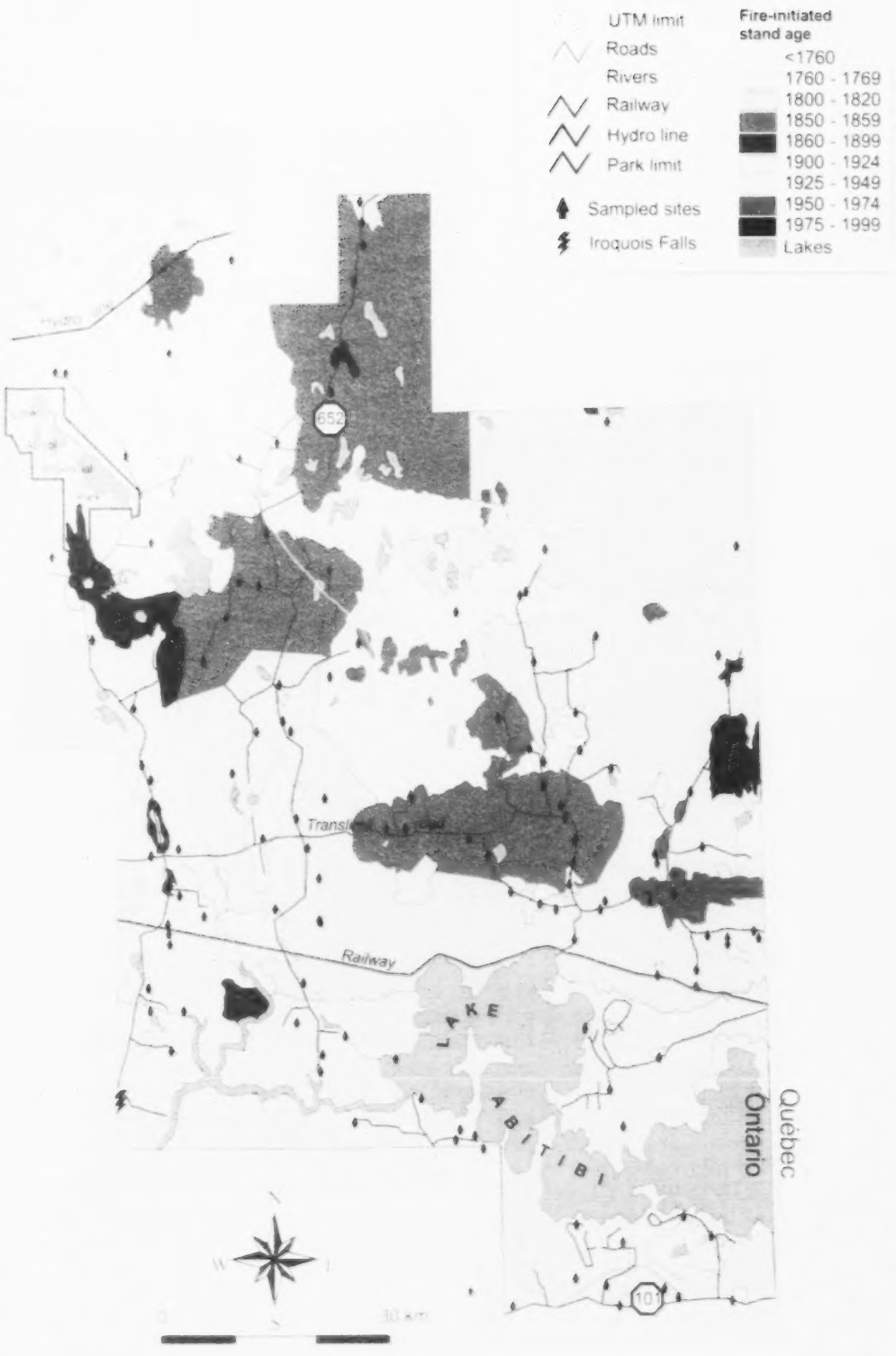

Figure 1. Time since fire map of the Lake Abitibi Model Forest.

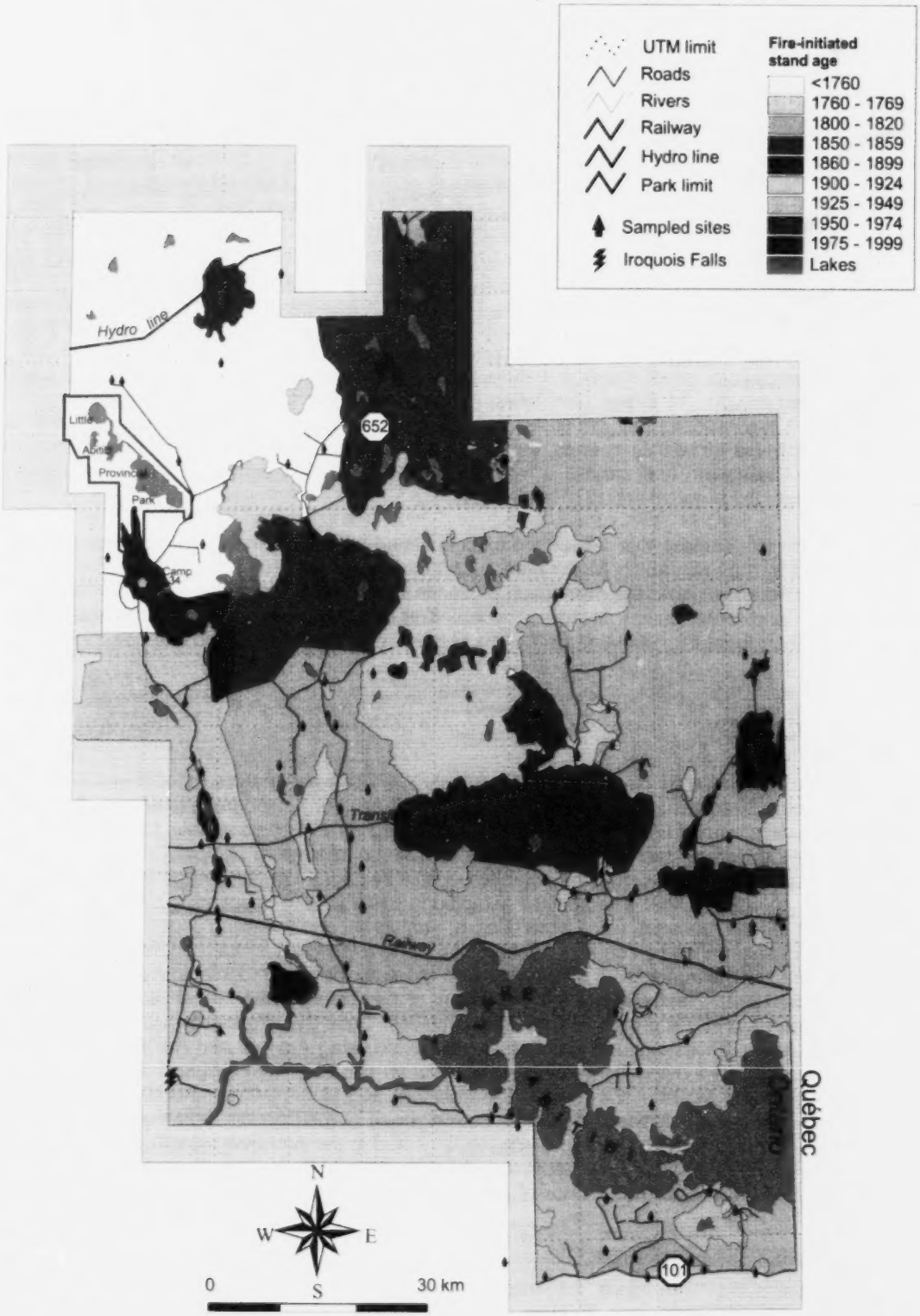

Figure 1. Time since fire map of the Lake Abitibi Model Forest.

RESULTS AND DISCUSSION

Time since fire map

The fire history reconstruction of the LAMF allowed us to make a time since fire map (Fig. 1) that shows the area originating from different fire decades. This map indicates that large portions of the forest have not burned for long time periods. Therefore, it suggests that fires are large in the LAMF, and that the intervals between successive fires at the same place are relatively long (see also Bergeron et al. 2001). This is in contrast with what is observed in the boreal forest of the central portion of the country, where old forests tend to be encapsulated into recently burned areas (Johnson et al. 1998). This will be important in the development of management strategies for the LAMF.

Age-class distribution

When the reverse cumulative area burned distribution is analyzed, it is obvious that the fire cycle has changed over time, as we do not observe a straight line (Fig. 2). The first change in the slope of the distribution, corresponding to a decrease in the rate of area burned annually, is observed around the mid-19th century. It is followed by another decrease in the early 20th century. Therefore, fire cycles were computed for different periods with relatively constant fire frequency (Table 1). A significant increase in fire cycle occurs over time, starting with cycles of less than 100 years before 1850 and increasing to cycles greater than 400 years after 1920. This increase in fire cycles appears to be related to a change in climate that occurred around 1850. This date corresponds to the end of the Little Ice Age (Bergeron and Archambault 1993). The observed decrease in fire danger in the region, which is correlated to the annual area burned since 1916, is in agreement with this hypothesis (Lefort et al., in press). The settlement of the area around 1920 may also have contributed to this increase through both passive and active suppression.

Figure 3 shows the age-class distribution of the entire Lake Abitibi Model Forest. Nineteen percent of the land base originated from fires that occurred in the 1910s and 1920s. Since then, there has been a general decrease in the area burned. Other major peaks occurred around 1850, 1810, 1760 and 1730. It is worth noting that almost 78% of the forest has not burned for more than 100 years (Table 1), 31% for more than 200 years, and 13% for more than 250 years. The average age of the forest stands is 172 years (Table 1). This average age is equivalent to the general fire cycle of the study area for the entire period of time under study. This is longer than what is generally expected for the boreal forest.

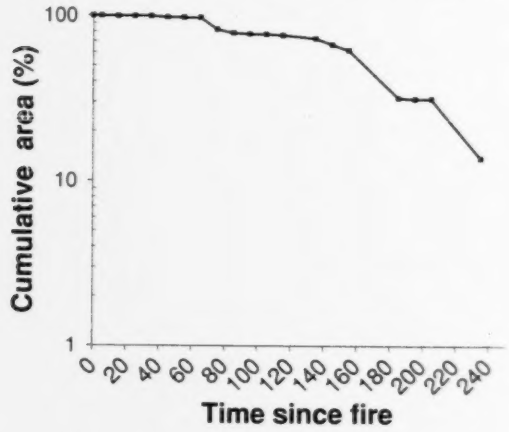

Figure 2. Reverse cumulative area as a function of time since fire in the Lake Abitibi Model Forest.

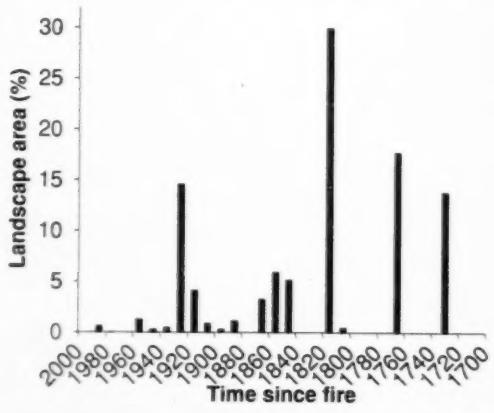

Figure 3. Area occupied by forest originating from different fire decades in the Lake Abitibi Model Forest.

Table 1. Age-class distribution characteristics of the Lake Abitibi Model Forest

Region	Area (km^2)	Mean age (yr)	% over 100 yrs	Fire cycles (yr)		
				1920-1999	1850-1920	<1850
Lake Abitibi Model Forest	8,245	172	78	422 (312-573)	196 (148-259)	78 (62-99)

Forest composition as a function of time since fire

Figure 4 shows the distribution of each model forest working group (WG) in terms of relative area occupied in each decade of origin. (Note that the Y-axis scale changes for each species). As expected, the jack pine WG, the white birch and the poplar WG (includes both trembling aspen and balsam poplar) all have their highest values in the stands that have burned within the last 100 years, with low importance after that period. Despite its general relative importance (~80%), the black spruce WG occupies an increasingly larger area in older stands, i.e., in stands that have not burned at least since 1860. The balsam fir WG also tends to become increasingly important with time since fire, and this WG is very rare in stands that have burned within the last 100 years. Finally, the white cedar WG is more abundant in the older stands. These results confirm that the dominance of various species is changing over time. Moreover the trends observed at the WG level are confirmed when looking at the relative proportion of the other species within each WG (Table 2). For instance, in the poplar WG, the relative proportion of black spruce and balsam fir tends to be higher in the stands older than 100 years whereas the relative proportion of white birch and jack pine tends to decrease after 100 years (Table 2). In the jack pine WG, the relative proportion of jack pine is slightly lower in stands that are older than 150 years. Moreover, jack pine shares its dominance mainly with black spruce which remains relatively stable in terms of relative proportion. In the black spruce WG, it is interesting to note that balsam fir seems to increase its relative importance with time since fire. The observed changes in the relative proportion of these species are similar to those observed in the forest in the adjacent Abitibi area of Québec (Gauthier et al. 2000).

An exploratory analysis of the trends in jack pine importance as a function of time since fire and surficial geology revealed that both till and sand are more favourable to jack pine than clay or organic deposits (Table 3). In fact, 44% of the stands with jack pine are located on sand whereas this deposit only represents 15% of the LAMF area. The analysis also indicated that only 2% of stands with jack pine are older than 200 years.

The same analysis for balsam fir revealed that this species does not grow well on organic deposits, which represent 12% of the LAMF, and where only 6% of the sites with balsam fir are observed (Table 3). The species is present on clay and till deposits approximately in the same proportion as these deposits are observed. On the other hand, balsam fir seems to have a preference for sandy deposits where 26% of the sites with balsam fir are observed, even if these deposits only cover 15% of the LAMF. Finally, this analysis also confirms that balsam fir is rare in stands that have burned recently (Table 3).

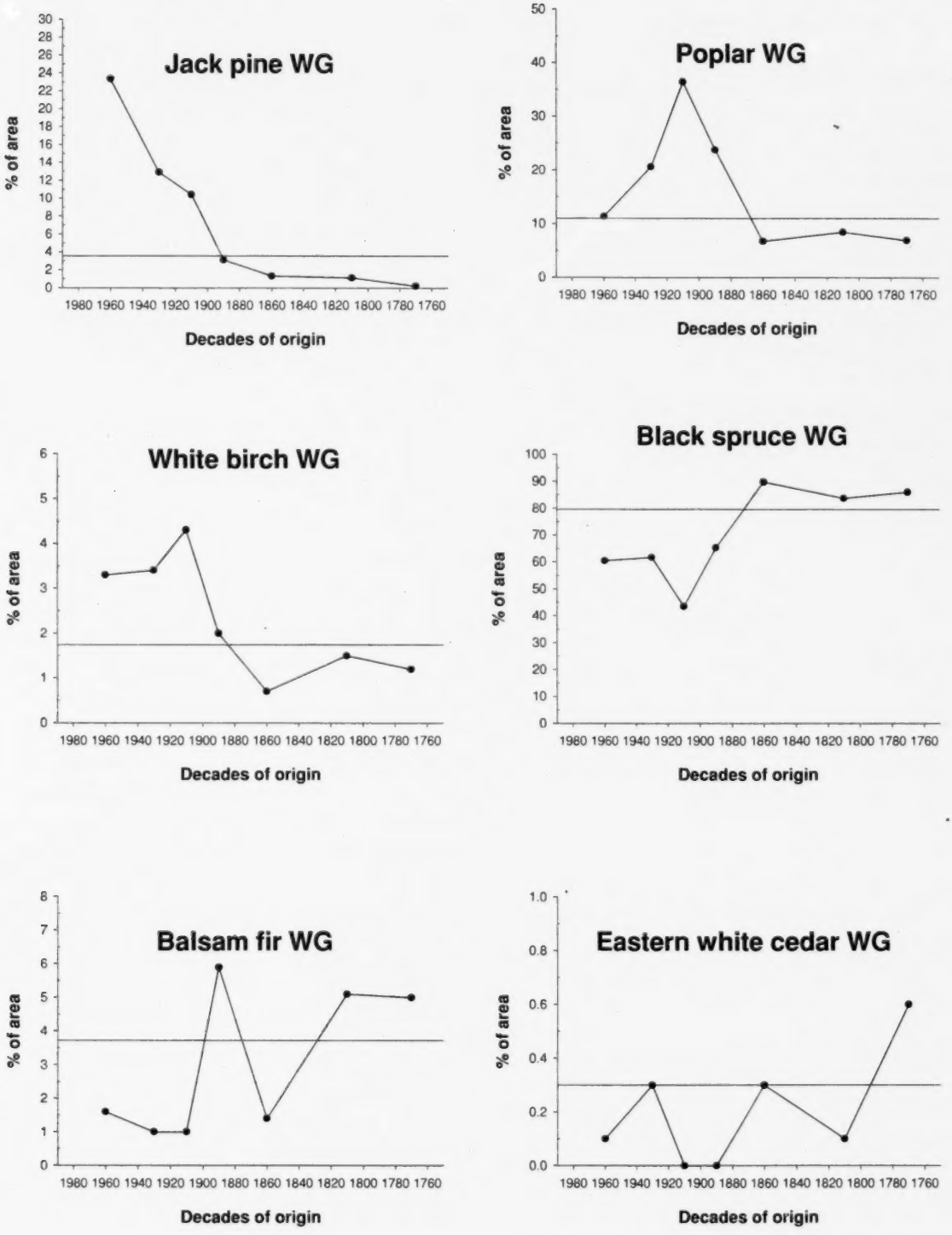

Figure 4. Relative area occupied by each working group as a function of decades of origin. The line indicates the average area occupied by the WG.

Table 2. Relative proportion of species importance in the four main working groups (WG) of the model forest.

Black spruce WG

	N	Sb	Bw	Pot	Pj	B
1940/1979	182	72	9	6	5	8
1920/1939	1252	80	4	9	5	2
1900/1919	247	76	4	7	8	5
1880/1899	135	79	5	7	1	9
1840/1879	1637	78	4	8	3	7
1800/1819	3220	76	4	8	2	9
1760/1779	2606	78	5	7	0	9
Mean		77	5	8	2	8

Poplar WG

	N	Sb	Bw	Pot	Pj	B
1940/1979	62	20	14	53	4	9
1920/1939	837	13	9	73	3	3
1900/1919	323	09	6	80	2	3
1880/1899	106	07	11	70	1	11
1840/1879	306	17	5	69	0	8
1800/1819	860	16	6	67	1	10
1760/1779	595	16	6	67	0	11
Mean		14	7	70	1	7

Balsam fir WG

	N	Sb	Bw	Pot	Pj	B
1940/1979	11	22	18	5	0	55
1920/1939	21	11	15	6	1	66
1900/1919	19	16	13	11	0	60
1880/1899	23	11	13	10	0	66
1840/1859	77	18	13	10	0	59
1800/1819	397	19	10	11	1	59
1760/1779	336	17	14	10	0	59
Mean		18	12	10	0	59

Jack pine WG

	N	Sb	Bw	Pot	Pj	B
1940/1979	82	15	4	5	75	1
1920/1939	393	22	3	7	67	0
1900/1919	104	22	0	6	71	1
1880/1899	17	14	1	6	79	0
1840/1859	47	21	2	9	68	0
1800/1819	157	23	1	6	68	2
1760/1779	14	19	19	1	61	0
Mean		21	3	7	69	1

N: Forest polygon number
Sb: Black spruce
Bw: White birch
Pot: Trembling aspen
Pj: Jack pine
B: Balsam fir

Table 3. Comparison of the relative proportion of occurrence of jack pine and balsam fir with the relative proportion of occurrence of the main surficial deposits of the LAMF as a function of century of origin.

Surficial deposit type proportions in the LAMF

	Fire century			
Type	1700	1800	1900	SUM
Clay	15.5	9.3	1.2	26
Till	11.4	25.5	10.3	47.2
Sand	4.7	7.6	2.7	15
Organic	2.1	8.9	0.7	11.7
SUM	33.7	51.3	14.9	100

Proportion of area where jack pine (Pj) is present

	Fire century			
Type	1700	1800	1900	SUM
Clay	0.2	2.9	0.1	3.2
Till	1.6	25	21.3	47.9
Sand	0.2	25.1	18.7	44
Organic	0	4.3	0.6	4.9
SUM	2	57.3	40.7	100

Proportion of area where balsam fir (B) is present

	Fire century			
Type	1700	1800	1900	SUM
Clay	10.8	13.4	0.4	24.6
Till	13.6	27.4	2.8	43.8
Sand	8.7	14.6	2.3	25.6
Organic	1.1	4.9	0	6
SUM	34.2	60.3	5.5	100

CONCLUSION/MANAGEMENT RECOMMENDATIONS

The results of the fire history reconstruction of the LAMF have revealed several important characteristics of the forest that should be taken into account in forest management. The first observation is that, with a mean time since fire of 172 years for the model forest, a large portion of the forested area exceeds the usual rotation age. Most of these older stands would be eliminated in an even-aged management strategy with a fully regulated forest under a rotation period of 100 years. The difference between the natural age-class distribution and the one under the current management system is fundamental because it implies, under fully regulated, even-aged management, the loss of over-aged forests, which are often judged essential to biodiversity maintenance, or a decrease in allowable cut due to longer forest rotations if the natural disturbance cycle is strictly adhered to. We suggest that the apparent incompatibility between these two aspects of sustainable forestry could be mitigated by the use of silvicultural practices designed to maintain specific structural characteristics of over-mature stands in forests under management (Bergeron et al. 1999). This approach may provide a means of maintaining species and ecosystem diversity while only slightly modifying allowable cut (Bergeron et al. 1999). To this end, it would be possible to treat some stands by clear-cutting followed by planting or seeding, homologous to fire; other stands by partial cutting or careful logging, which simulates the natural evolution of over-mature stands; and still others by selection cutting as a means of emulating gap dynamics in old growth. We suggest that the average forest stand age, 172 years for the LAMF (in terms of time since fire), could be used as a baseline in strategic planning of harvesting activities in order to estimate the

desired proportion of the three cohorts under different silvicultural treatments (Bergeron et al. 1999). In the LAMF case, with a maximum harvesting age of 100 years, 43% of the stands (in area) would be treated as cohort I, 25% as cohort II and 32% as cohort III.

Our results have also shown that species composition and, potentially, species structure appear to change along the chronosequence. This indicates that deciduous species are an important component of forest stands in the LAMF, mainly in young stands. The approach developed in the Lake Duparquet experimental and teaching forest could serve as a basis for the management of these mixedwood stands (Harvey and Leduc 1998; Harvey et al. 2002). For the black spruce and jack pine stands, the model proposed by Bergeron et al. (1999) also constitutes a preliminary model for the management of these stands. The current tests using harvesting with regeneration protection (HARP) (known as "CPPTM" in French) (MacDonell and Groot 1996) in the model forest are a promising avenue to the uneven-aged management of black spruce stands.

A final observation is that it might be important to consider surficial deposits and drainage classes in the development of management strategies, as species preference and consequently forest dynamics differ from one surficial geology type to another.

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